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Design and Fabrication of a Motorized Twenty-Five (25) Ton H-Type Hydraulic Press

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Abstract: This research presents the design, fabrication, and performance evaluation of a 25-ton (24,5166.25N) hydraulic press capacity machine to withstand a maximum load of 25 tons without failure. The conceptualized design is fully realized using various equations, simulations, and analysis. Mild steel was used predominantly in the design due to its strength, machinability, and rigidity which falls within the design specification. The low-cost and hydraulically operated press uses a mix of locally and imported sourced materials. The hydraulic press components are the frame column, the working table, the frame, the top support plate, the hydraulic cylinder, the pump, the oil reservoir, the motor, and the directional control valve. In evaluating the performance of the hydraulic press machine, mild and carbon steels of varied thicknesses of 10 mm, 15 mm, and 25 mm were tested. In respect of the mild steels, the pressure gauge recorded 1 MPa, 10 MPa, and 16 MPa after pressing them while that of carbon steels pressed recorded 10 N/mm2, 12 N/mm2and 18 N/mm2. These made corresponding deflections of 30 mm, 40 mm, and 12 mm for the mild steel and 8 mm, 10 mm, and 15 mm for the carbon steel. At a pressure beyond 31.5 MPa being the set point of the directional control valve, the motor or pump ceases to work, resulting in the inability of the press to function. The practical test result obtained is devoid of oil leakages, low pressure, abnormal noise, and excessive overheating of the system.

Keywords: Hydraulic press, maximum load, load resistance, pressure gauge, piston, cylinder.

1. Introduction

Hydraulic press is a pressure-exerting machine tool used for deforming metallic objects by pressing and hammering action (IJRESM_V1_I10_168, n.d; Kaushik, 2013). The development of engineering over the past has been the search for more efficient and convenient means of pushing and pulling, rotating, thrusting, and controlling the load, ranging from a few kilograms to thousands of tons (Mandavade & Sagar Sonawne, 2020; Sumaila et al., 2011). Press machines are widely used to achieve almost all the above operations. Presses are used in industry for the cold working of metallic objects into a variety of shapes through operations such as blanking, piercing, chawing, forming, bending, and shearing. All presses consist of a machine frame supporting a bed, a ram, a source of power, and a

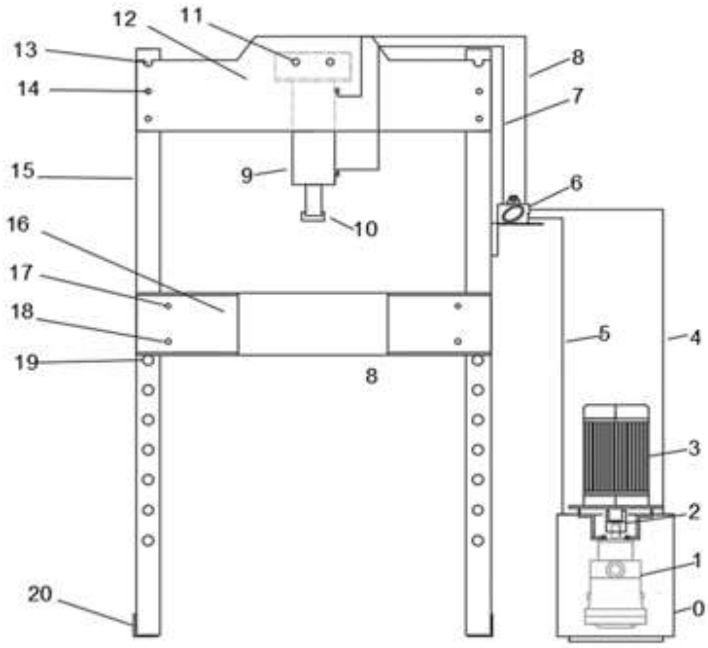
prime mechanism (Adesina et al., 2018; Paul & Kumar, 2019). According to Sumaila et al., (2011), press machines represent an important part of the manufacturing and maintenance industries in the production of cheap and large quantities of components such as motor/car bodies, electric motor parts, domestic electrical appliance parts, and bench work in maintenance shops. Presses can be classified into three principal categories as hydraulic presses which operate on the principles of hydrostatic pressure, screw presses which use power screws to transmit power and mechanical presses which utilize kinematic linkage of elements to transmit power (Asim & Kamate, 2021.)
A look at the engineering workshops in Ghana reveals that the above-mentioned standard machines are imported into the country with hard currency. The few ones that are manufactured locally are often challenged with oil leakages, overheating, slow pressure build-up, and abnormal noise. This project sought to design and fabricate a hydraulic press machine that would be comparatively low-cost and hydraulically operated using a mix of locally and imported sourced materials. This will not only help to recover the monies lost in the form of foreign exchange to Ghana but will improve the level of local technology in the use of hydraulic fluid power transmission.

A research work presented by Khatib et al. (2020), sought to design and fabricate a 5-ton hydraulics Press Machine. In the project, the press frame, cylinder, and press table were all designed by the design procedure and analyzed to improve their performance and quality for press working operations (Manakur et al., 2019). Using the optimum resources possible in designing the hydraulic press components, results in cost reduction by optimizing the weight of the material utilized for building the structure (Zheng et al., 2022). The detailed drawing of the developed hydraulic press machine was done using SolidWorks software. The project aimed at mass minimization of H-frame type hydraulic press and at the same time to compensate the forces acting on the working plates and has to fulfill certain critical constraints. The study aimed at integrating the mechanical system of the hydraulic press with the hydraulic system to facilitate the ease of operation to manufacture smaller parts in bulk. Thus, with the aid of automation, the production time could be reduced for a higher degree of accuracy to be achieved as the human efforts will be alleviated (Parthiban et al., 2014).

Nandvadekar et al. (2008), designed and developed a Hydraulic Dowel Pin Pressing Machine which works under impact load conditions. Because of continuous impact load, some parts of the machine experience compressive stress, and other parts experience tensile stress (Sezgen et al., n.d.). To overcome this problem, optimization of the machine is required which was done using CAD tools and analyzed in finite element analysis tools such as ANSYS (Khandekar, 2015; Vaishnav et al., 2016). This is an attempt to provide the smooth and rapid functioning of press work with the help of a hydraulic system (Shravan Kumar & Prashanth, 2017). Amiolemhen & Ogie (2019), also designed and manufactured a 10-tonne hydraulic press for laboratory use in higher institutions using locally sourced materials. Frames and cylinders were the main components of the hydraulic press. An existing design was examined and the basic features and components were identified after which a market survey was conducted to assess the availability or otherwise of the components. The major components of the press design include the cylinder and piston arrangement, the frame, and the hydraulic circuit. The machine was then designed and produced according to specification and was subsequently calibrated and tested (Sumaila et al., 2011). The principal parameters of the design included the maximum load of 10 tonnes, the distance of the load resistance, the system pressure, the cylinder area, and the volume flow rate of the working fluid.

2. Materials and Methods

Components of the hydraulic press machine were designed using various design equations and modeling. A detailed drawing of the developed hydraulic press machine was produced using SolidWorks. Abaqus was used for modeling, simulation, and analysis of the stressed-prone areas of the hydraulic press machine. In fabricating the machine, mild steel and stainless were used for most parts of the components such as the U-channel, angle iron, shafts, pipes, and plates. A well-labeled drawing of the hydraulic press with all the components and part list is shown in Figure 1. Typical chemical composition and mechanical properties of mild and stainless steels are shown in Tables 1 and 2 respectively.



PARTS NAME	
0	Oil Tank
1	Oil pump
2	Flexible Coupling
3	Electric Motor
4	Oil Return Line(pressure hose)
5	Oil Lift Line (Pressure Hose)
6	Directional Control Valve
7	Cylinder Pressure line (Pressure pipe)
8	Cylinder return line in Pressing)
9	Hydraulic Cylinder
10	Changeable Piston Cap
11	Cylinder Mount Stud (2x)
12	Upper Plate (2X)
13	Upper Plate Pin (2x)
14	Upper Plate Stud (4X)
15	Frame Column (2x)
16	Working Table (2x)
17	Table Spacer (2x)
18	Table Roller (2x)
19	Working table Pin (2x)
20	Foot (2X)

Figure 1: Labeled drawing of the press with all the components.

Source: This study, 2023.

Table 1. Chemical composition of mild and stainless steels

Material			**Elements**		
	C	**Si**	**Mn**	**S**	**P**
			Composition		
Mild steel	0.16	0.40% Max	0.7	0.040% Max	0.040% Max

					Elements			
	C	**Mn**	**Si**	**Cr**	**Ni**	**S**	**Mo**	**N**
					Composition			
Stainless Steel	0.08	2.00	0.75	16.0-18.0	10.0-14.0	0.030	2.0-3.0	0.10

Source: Universal Steel Company, Ogba Industrial Estate, Ikeja Lagos.

Table 2. Mechanical properties of mild and stainless steels

Material	**Tensile Strength (MPa)**	**Yield Strength (MPa)**	**Elongation (d, %)**	**Elasticity Modulus (GPa)**	**Poison Ratio**
Mild steel	365	305	20	205	0.28

Stainless steel	485	170	10	193	0.25

Source: Universal Steel Company, Ogba Industrial Estate, Ikeja Lagos.

Simulation of Hydraulic press

Static Structural Analysis and Boundary Conditions

n

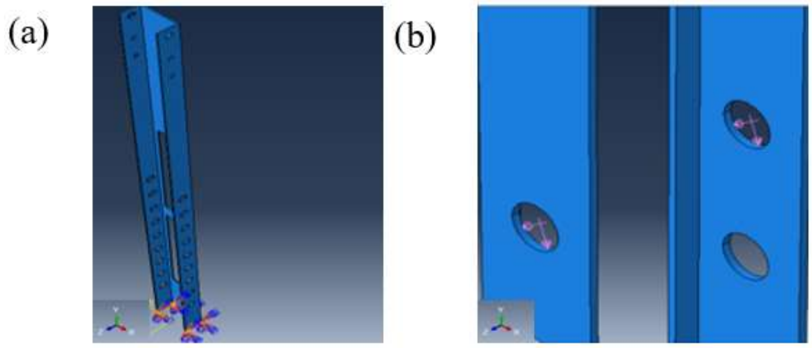


Figure 2: Static Structural Analysis and Boundary Conditions (a) Fixed type constraint to the base of the stand (b) Force of 122583.125 N applied on frame column

In the boundary conditions used on the working table pins, the total pressure was divided into two on each working table pin with 25 tons load as shown in figure 3.

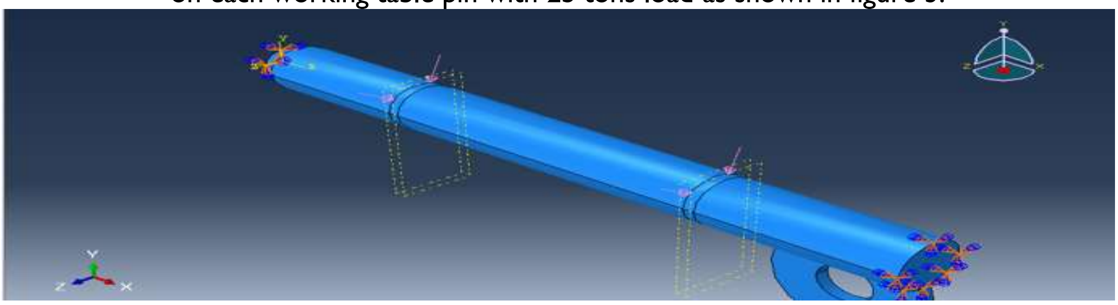


Figure 3: Boundary Conditions with force 122583.125N applied on the pin of the working table.
Source: This study, 2023.

Figures 4 and 5 show boundary conditions used on the working table where the pressure acting on the working table is divided into two. The pressure acting on the working table is concentrated at the center of the table due to the simply supported beam nature of the press.

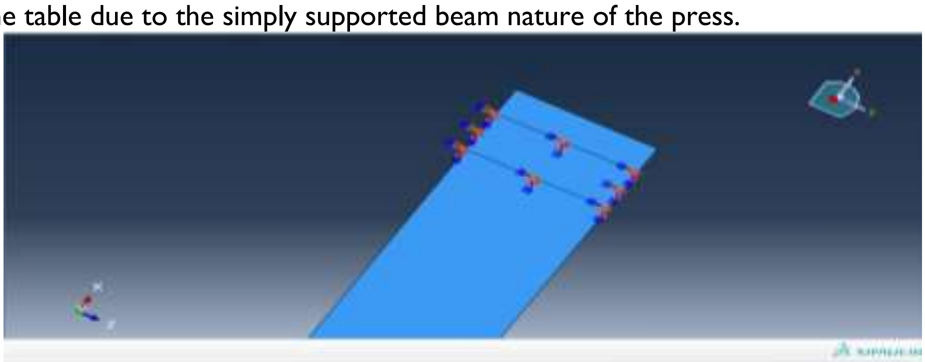


Figure 4: Boundary Conditions Applied on working table.

Source: This study, 2023.

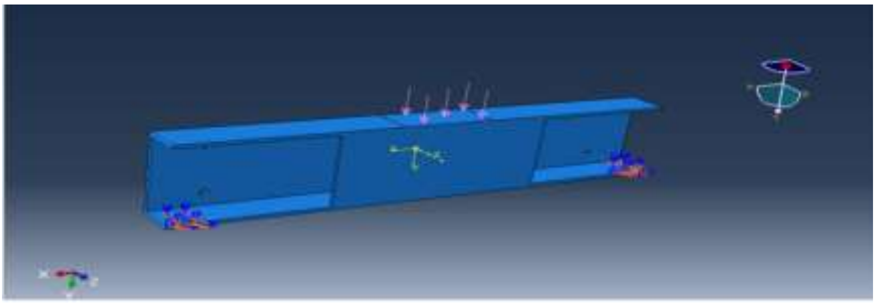


Figure 5: Force of 122583.125 N acting on working table.
Source: This study, 2023.

Design and Fabrication Analysis of the Hydraulic Press.

Some of the parts of the hydraulic press designed are; the frame column, base and top support plate of the press, studs, working table, arbor plate, space and rollers table, and hydraulic cylinder and pump.

Design, Stress, and Deflection Analysis on Machine Components.

Area of the U- channel Frame column and working table;

$$A = 2bt_f + (h-2t_f)\, t_w \quad (1)$$

Area Angle iron foot of the frame Column;

$$\text{Area } A_0 = \text{depth (h)} \times \text{thickness (t)} \quad (2)$$

$$\text{Area } A_1 = [\{\text{width (w) - thickness (t)}\} \times \text{thickness}] \quad (3)$$

$$\text{Area of stud for the cylinder, } A = \pi r^2 \quad (4)$$

Area of stud for fastening the upper plate to the frame column, upper plate pin, working table pin is given by

$$A = \pi r^2 \quad (5)$$

Shear Stress-induced in studs

Shear Stress-induced in studs used to hold the cylinder u channel mount,

$$\tau_{max} = P/A \quad (6)$$

Shear Stress-induced in studs used to hold the cylinder u channel mount and the wildered locator,

$$\tau_{max} = P/A1 + A2 \quad (7)$$

Consideration of the working table for the different profile. The hollow rectangular part of the working table is shown in figure 6.

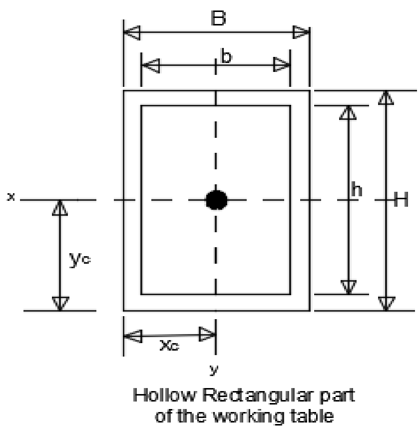


Figure 6: Working Table-Hollow channel.

Source: This study, 2023.

Area of the hollow rectangular part working table,

$$A = BH - h\,b \tag{8}$$

Centroid hollow rectangular part working table.

$$C_x = \frac{B}{2} \tag{9}$$

$$C_y = y = \frac{H}{2} \tag{10}$$

Area moment of inertia hollow rectangular part working table

$$I_{xx} = \frac{BH^3}{12} - \frac{bh^3}{12} \tag{11}$$

$$I_{yy} = \frac{HB^3}{12} - \frac{HB^3}{12} \tag{12}$$

Section Modulus of the hollow rectangular part working table

$$Z = \frac{BH^3 - bh^3}{6H} = \frac{I}{y} \tag{13}$$

The C channel part of the working table is shown in figure 7.

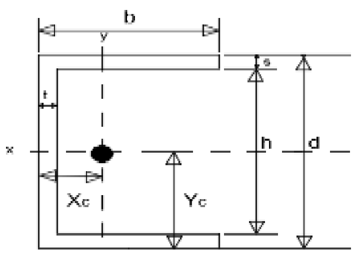


Figure 7: Working Table-C channel.

Source: This study, 2023.

Area of the U - Channel part of the working table,

$$A = bd - h\,(b - t) \tag{14}$$

Centroid of the u-channel part of the working table

$$C_x = \frac{2b^3 s + ht^3}{2bd - 2h(b-t)} \tag{15}$$

$$C_y = y = \frac{d}{2} \tag{16}$$

Moment of Inertia of the U- channel part of the working table

$$I_{xx} = \frac{bd^3 - h^3(b-t)}{12} \tag{17}$$

$$I_{yy} = \frac{2sb^3 + ht^3}{3} - AC_x \tag{18}$$

Section Modulus of U- channel part of the working table

$$Z = \frac{I}{y} \tag{19}$$

Bending Moments on the working table considering the hollow rectangular part of the working table.

$$M = \frac{PL}{4} \tag{20}$$

Where

M= maximum Bending Moment

P= Applied Force = 245166.25 N

L= Length of working Table = 1092 mm

$$M = \frac{245166.25 \times 1092}{4} = 66930386.25\ Nmm$$

Deflection for a beam supported at both ends with load at the Centre

Maximum Deflection (δ)

$$\delta = \frac{PL^3}{48EI} \tag{21}$$

Where

P= load = 245166.25N

L= length of the working table = 1092 mm

E= Modulus of elasticity = 200GPa

I= Moment of Inertial of the hollow part of the working table = 24870556.86

Bending Stress on the working table

$$\sigma = \frac{My}{I_{xx}} \tag{22}$$

σ = Bending Stress

y= Perpendicular distance to the neutral axis in mm = 101.6mm
$\mathrm{I_{xx}} = \text{Moment of initial } = 24870556.86\text{mm}^4$

The Shear force and a bending moment diagram of the simply supported beam of 25 tonnes hydraulic press is shown in figure 8.

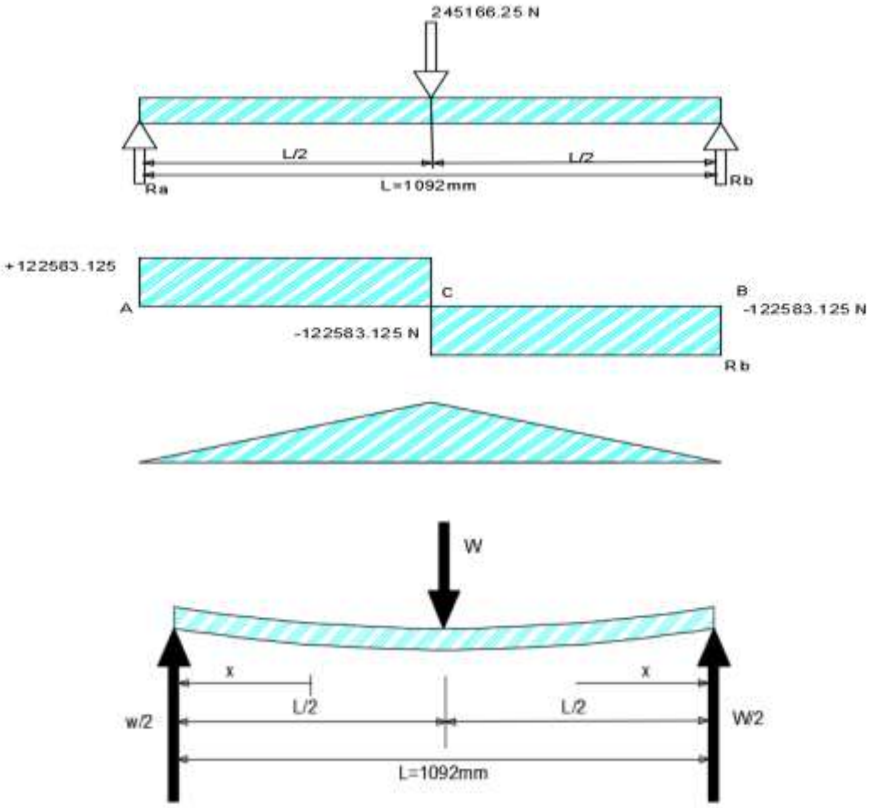


Figure 8: Shear force and a bending moment of a simply supported beam of 25 tons (245166.25N)

Source: This study, 2023.

The hydraulic press was fabricated using a cylinder made locally from an old cylinder, U- channel, a 10 mm plate and various types of fasteners (bolts and nuts, and screws) were bought from the local market. Details of some of the components used in the fabrication of the press are shown in figure 9 through to figure 21. Fabricated components were joined together through electric arc welding. The principal designing parameters included the piston stroke, maximum load, cylinder bore, volume flow rate of the working fluid, and system pressure. The important design components included a hydraulic cylinder, a hydraulic circuit, and the main structure of the system known as a frame.

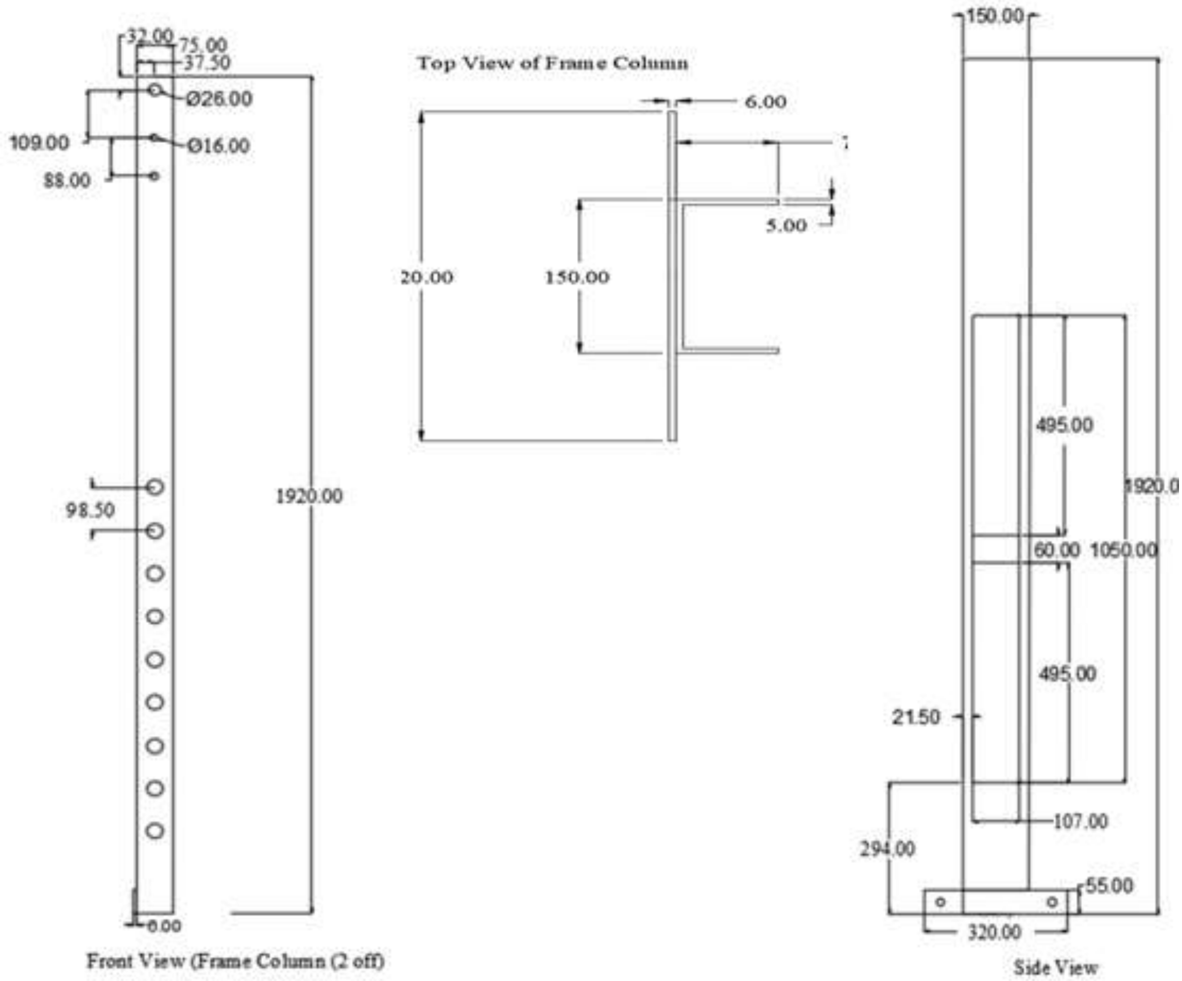


Figure 9: Detailed drawing of Frame Column.

Source: This study, 2023.

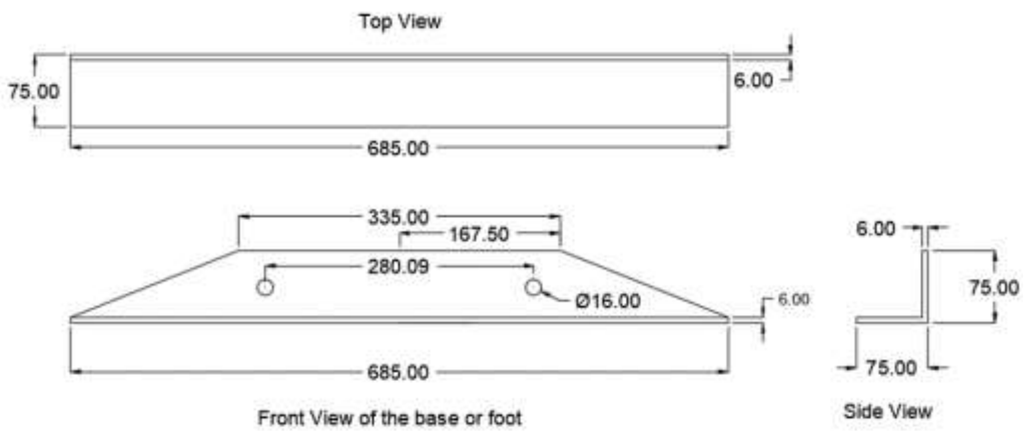


Figure 10: Detailed drawing of foot or base of press.

Source: This study, 2023.

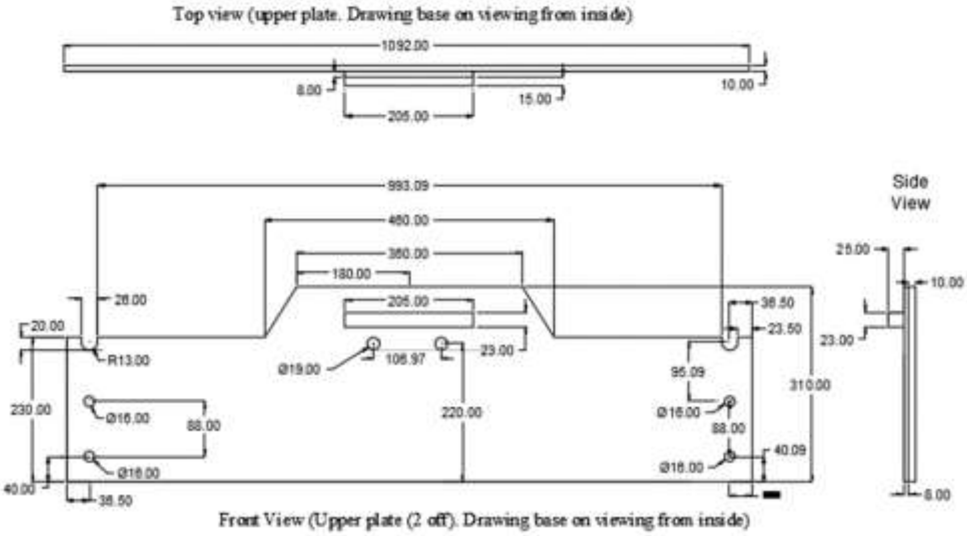


Figure 11: Detailed drawing of top support plate of the press.

Source: This study, 2023.

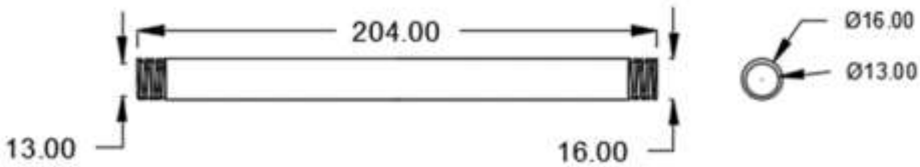


Figure 12: Detailed drawing of upper plate stud.

Source: This study, 2023.

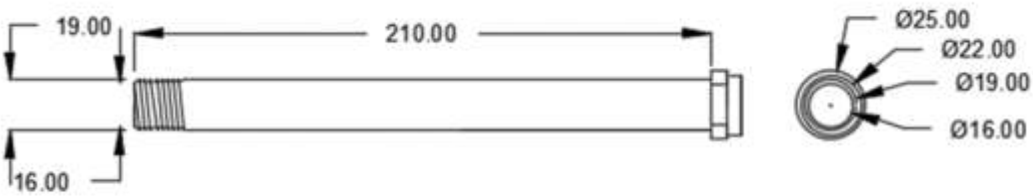


Figure 13: Middle upper plate stud for cylinder mount between the two plates.

Source: This study, 2023.

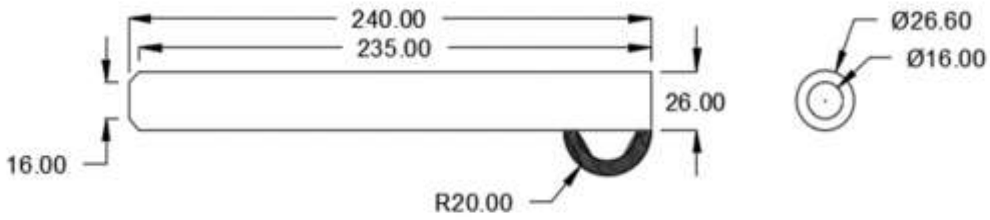


Figure 14: Upper plate end pins.

Source: This study, 2023.

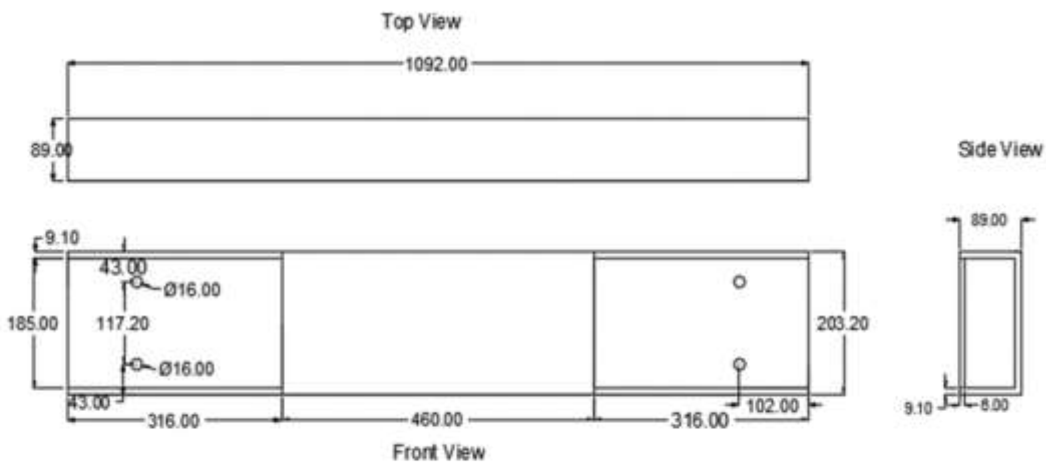


Figure 15: Detailed drawing of working table.

Source: This study, 2023.

Figure 16: Detailed drawing of Arbor plate.

Source: This study, 2023.

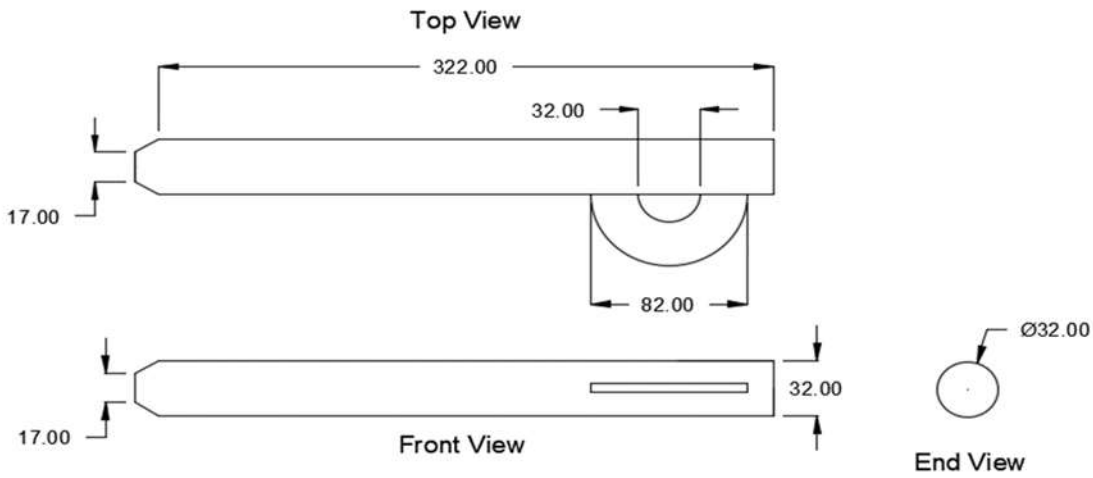


Figure 17: Detailed drawing of table pin.

Source: This study, 2023.

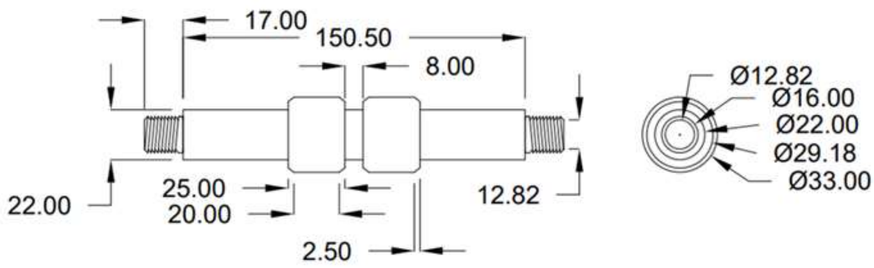


Figure 18: Detailed drawing of table spacer.

Source: This study, 2023.

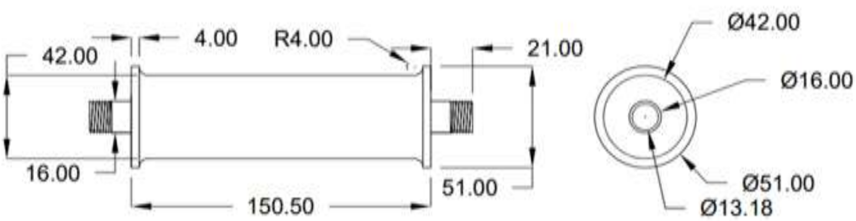


Figure 19: Detailed drawing of table roller.

Source: This study, 2023.

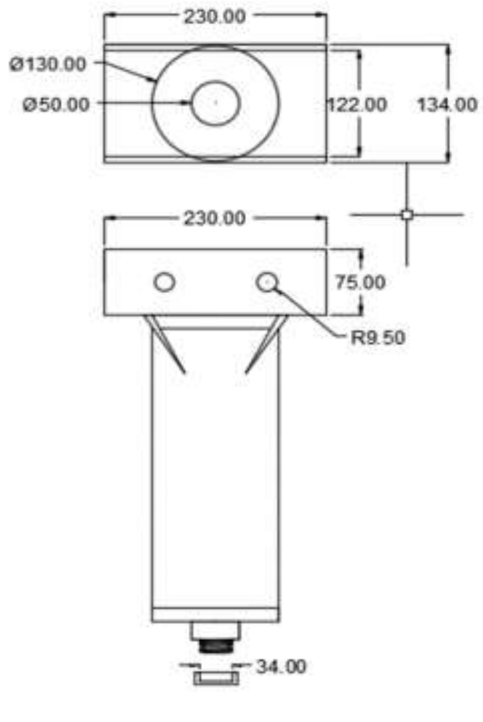


Figure 20: Detailed drawing of hydraulic cylinder with welded wedged u-shaped iron mount.

Source: This study, 2023.

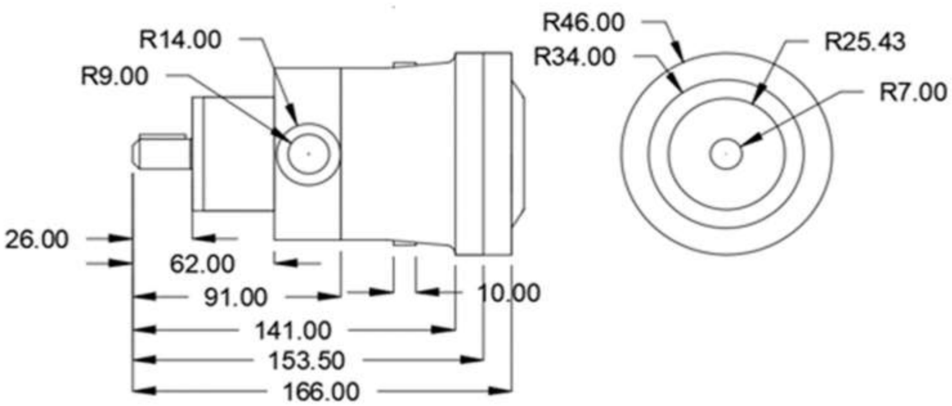


Figure 21: Oil Pump.

Source: This study, 2023.

A 1PA4F-QW directional control valve is used for the design and is manually operated. It is used to direct the flow from the pump to the double-acting cylinder to allow the opening and closing (press or release) of the hydraulic cylinder. Table 3 gives detailed technical data on the DCV.

Table 3. Technical data of Directional Control Valve.

Parameter	Value
Ambient temperature	-40c ….. +60C
Viscosity	12.800mm2/s
Fluid temperature Fluid temperature	-150C …+.80C
Filtration	10 to NAS 1638
Max operating pressure	31.5 MPa
Back pressure	5MPa
Nominal flow	40 l/min
Leakage(A,B-T)	15cm3/min at 12.MPa
Spool stroke	6 mm
Actuating force	< 200 N
Modification/ Spools	with 1 to 7 (11gp).

Source: www.vinckehydraulics.com, 2016. (accessed, 2023)

A check valve was fixed on the hydraulic system to allow the flow of the hydraulic fluid in one direction, preventing the reverse path. The hydraulic pump used in the design is a piston type, and it was employed due to its high and positive pressure delivery. Table 4 gives the technical data of the oil pump and figure 21 shows the selected pump.

Table 4. Technical Data of the selected oil pump

Name	2.5MCY14-1B axial piston pump
Material	cast iron
Drive mode	Electric
Normal pressure	Normal pressure
Rated displacement	2.5cc/rev
Theoretical flow (l): 1000rpm	2.5 / 1500rpm: 3.75 Maximum drive: 6KW

Source: www.vinckehydraulics.com, 2016. (accessed, 2023)

The prime mover associated with this work was selected based on its speed, torque level, and power capacity. A three-phase motor of 4 kw of horsepower with a speed of 1450 rpm was selected for this work.

Fabrication process

Measurements, cutting of component parts to required sizes and various joining methods were employed for the fabrication of the hydraulic press as shown in figures 22 to 24.

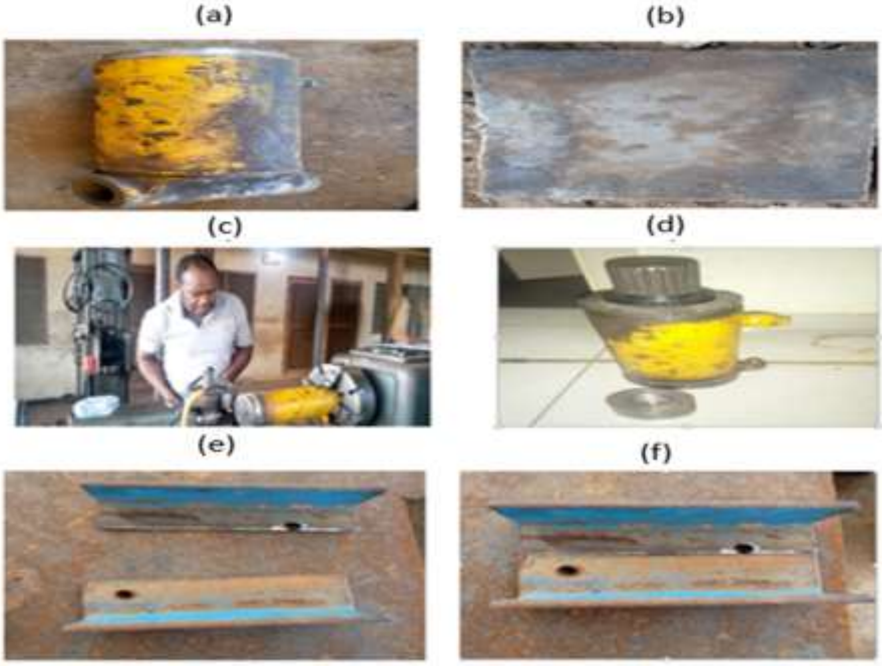


Figure 22: Fabrication of the hydraulic cylinder (a) Cutting cylinder to length from old cylinder. (b) Preparing bottom plate for the cylinder (c) Turning of the cylinder welded to bottom plate. (d) Machining of two different press cups. (e) Cutting of angle iron for cylinder mount (f) Welding of joint cut and angle irons to the bottom.

Source: This study, 2023.

Figure 23: Fabrication of the frame of the press with the cylinder (a) Marking out of the upper plate. (b) Cutting all the U-channel materials to length. (c) Cutting the marked plate to shape for the upper plate. (d) Clamping the cut upper plate to the cut frame columns to position for drilling and marking out position for cylinder mount.

Source: This study, 2023.

Figure 24: Setting up hydraulic pack. (a) Setting and mounting of DCV. (b) Setting and mounting the pump and the motor. (c) Connecting the hydraulic pack to the hydraulic cylinder. (d) Setting the DCV to the required maximum operating pressure of 24.5 MPa.

Source: This study, 2023.

Experimental Test

The fabricated hydraulic press was taken through a series of testing with different material thicknesses to ascertain the workability of the press (Ufuoma Oreko & Emagbetere, 2019). Table 5 shows the mild and carbon steel materials and their respective thicknesses used for the experiment. A rectangular plate as shown in figure 25 was used throughout the testing.

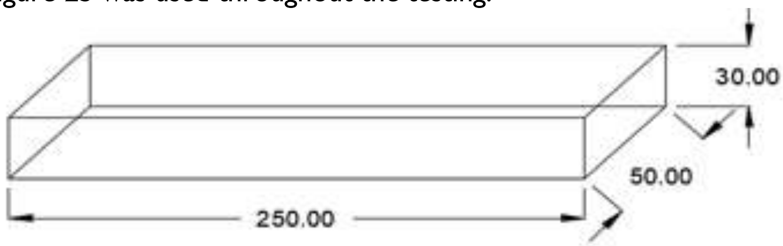


Figure 25: Dimension of material specimens.

Source: This study, 2023.

Table 5. Experimental Test

Material A	Material B	Thickness/mm
Mild Steel	Carbon Steel	10
Mild Steel	Carbon Steel	15
Mild Steel	Carbon Steel	20
Mild Steel	Carbon Steel	25
Mild Steel	Carbon Steel	30

Source: This study, 2023.

3. Results and Discussion

Stress and deformation in stand

In the stand, a stress of 310 MPa was generated due to applied load as shown in figure 26, and a total deformation of 0.59 mm was obtained due to the applied load as shown in figure 27.

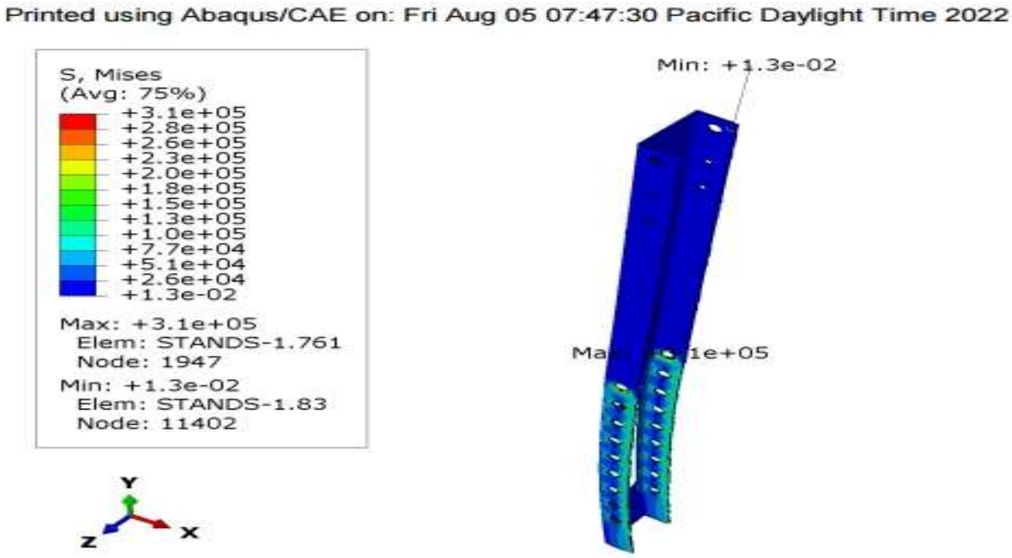


Figure 26: Maximum stress on frame column.

Source: This study, 2023.

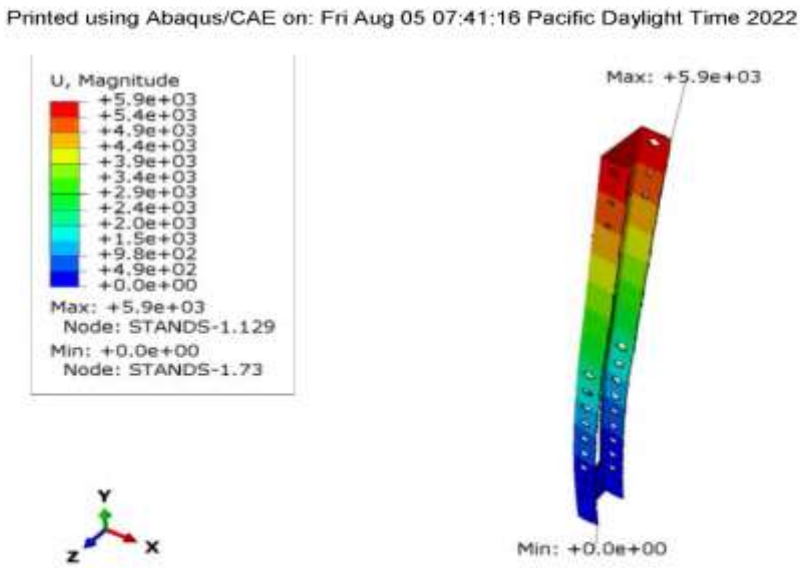


Figure 27: Maximum Displacement on frame column.

Source: This study, 2023.

Stress and deformation in Working Table pin.

The pressure points considered in analysis are the point of contact between the pin and the working table. Figure 28 and figure 29 Maximum show the working table pin subjected to applied load generated a stress of 310 MPa in the pin due to applied load. Total deformation obtained due to the applied load was 0.59 mm.

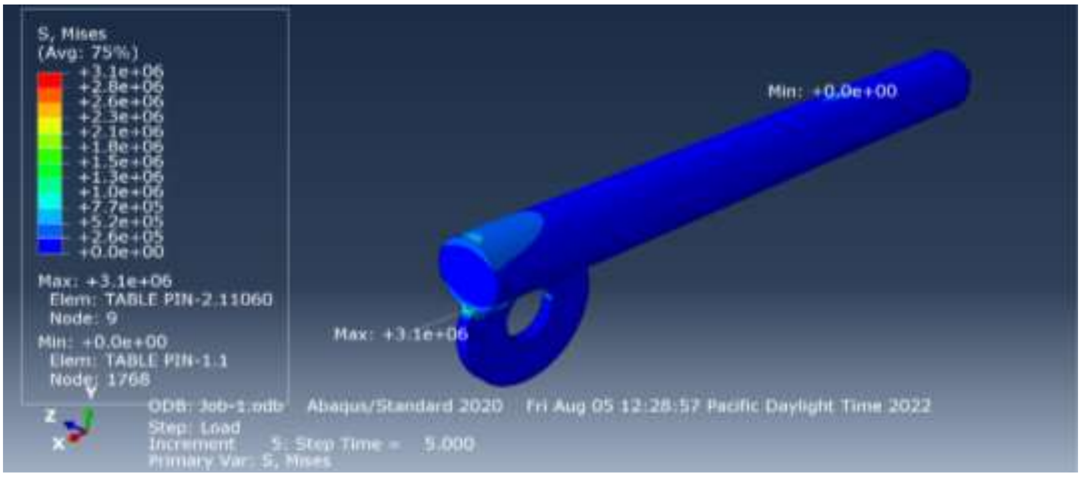


Figure 28: Maximum Stress on Working Table Pin.

Source: This study, 2023.

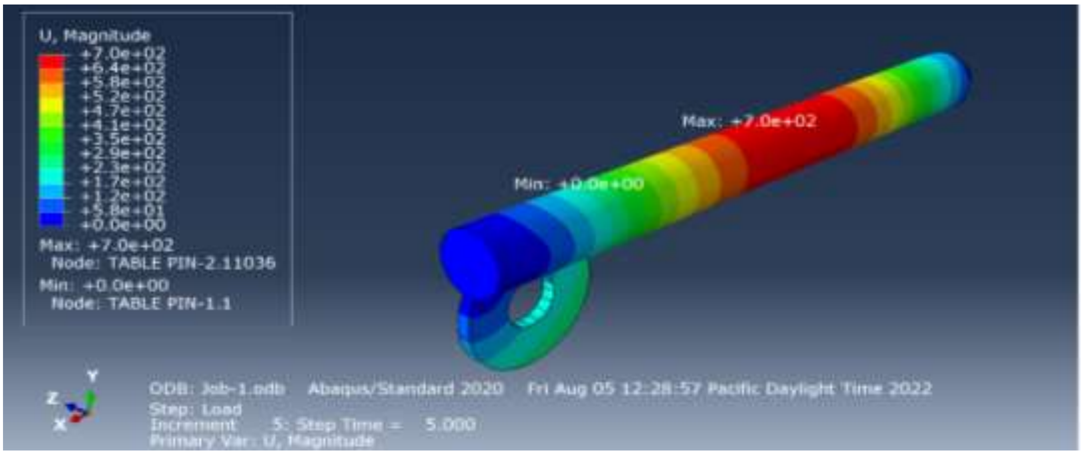


Figure 29: Maximum displacement on working Table Pins.

Source: This study, 2023.

Stress and deformation in working table.

Figures 30 and 31 show, the working table was subjected to the maximum applied load and , a stress of 195 MPa was generated in the stand due to applied load. Total deformation of 0.17 mm is found due to the applied load in the working table.

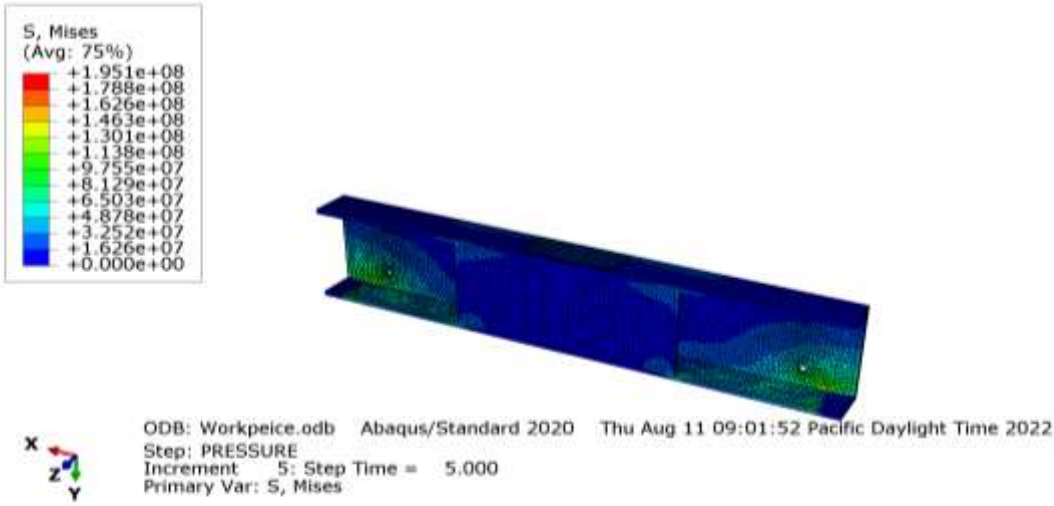


Figure 30: Maximum Stress on working table.

Source: This study, 2023.

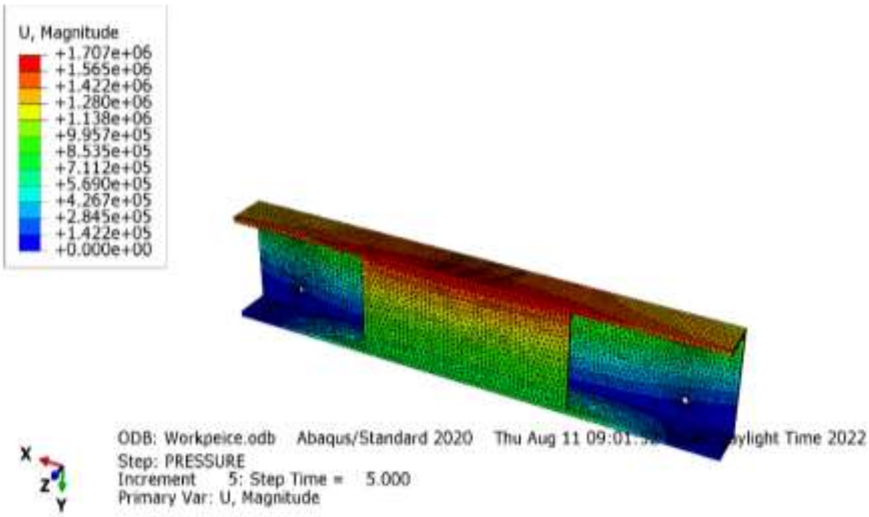


Figure 31: Maximum displacement on working table.

Source: This study, 2023.

Stress and deformation in the full assembly

The fully assembled press was subjected to full load static simulation which produced a stress of 280 MPa in the stand due to the applied load as shown in figure 32. Total deformation of 0.19 mm was found in the full assembly.

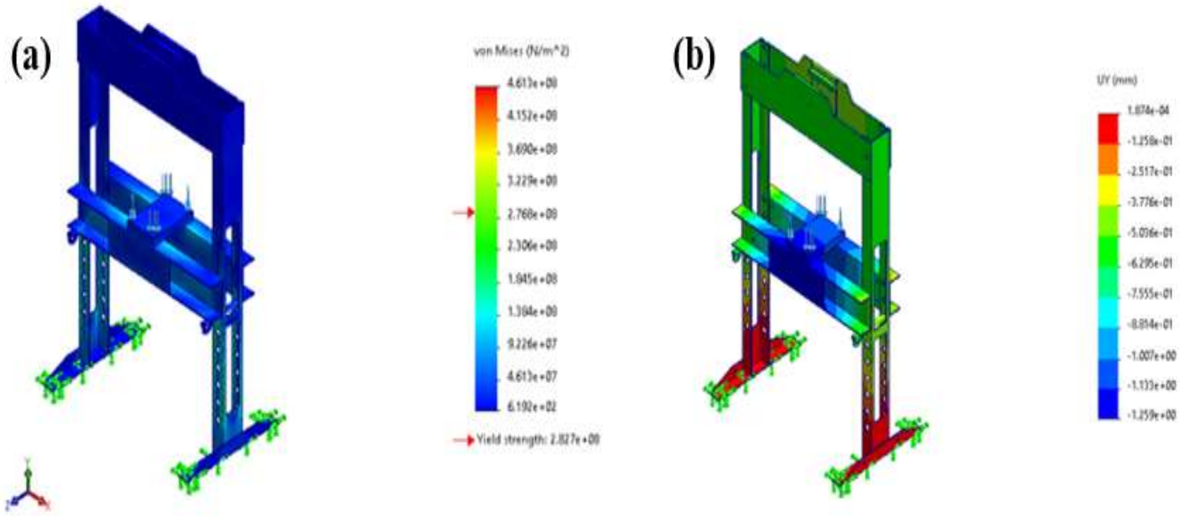


Figure 32: Stress and displacement analysis (a) Maximum Stress **(b)** Maximum Displacement.

Source: This study, 2023.

Factor of Safety

From the analysis in figure 33, it was found out that the design was fit to manufacture. After taking it through the analysis with the amount of force applied, the factor of safety (FOS) distribution was 1.2, which makes it safe to manufacture.

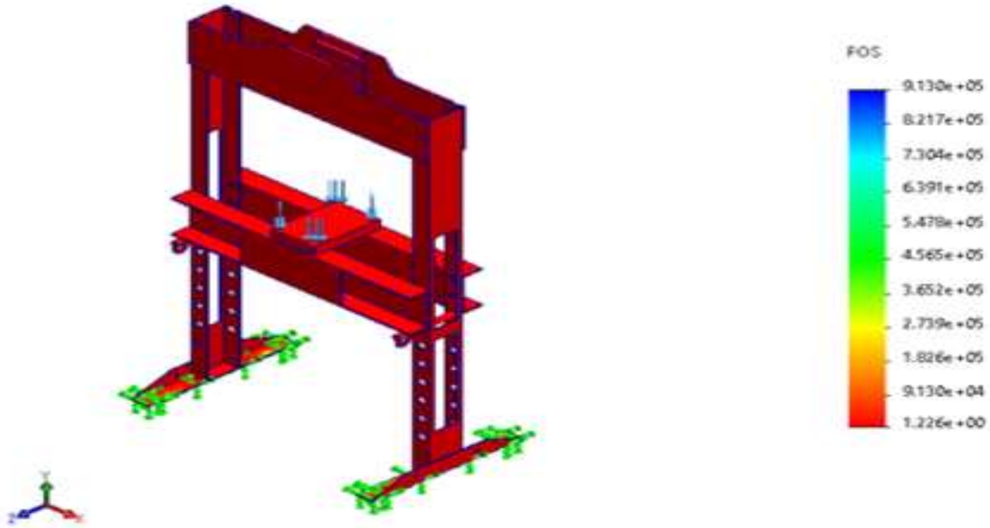


Figure 33: Assembled press.

Source: This study, 2023.

After the press was tested experimentally with different thickness of mild and carbon steels the following results were obtained as shown in Table 6. The tested materials were cut to 250 mm length and 50 mm width.

Table 6: Experimental Test Results

Material used	Thickness/mm	Deflection/mm	Pressure/MPa
Mild Steel	10	30.0	1.0
Mild Steel	15	40.0	10.0
Mild Steel	20	16.0	12.0
Mild steel	25	12.0	16.0
Mild Steel	30	9.0	19.0
Carbon Steel	10	8.0	10.0
Carbon Steel	15	10.0	12.0
Carbon Steel	20	16.0	14.5
Carbon Steel	25	15.0	18.0
Carbon Steel	30	10.0	21.0

Source: This study, 2023.

Pressure against thickness graph

From figure 34(a), the pressure of the press exerted on the test materials is plotted against the thicknesses of the test materials. The thickness of 10mm was pressed, and the pressures obtained were 1 MPa and 10 MPa for mild steel and carbon steel respectively. At a thickness of 20 mm, the press generated pressures of 12 MPa and 14.5 MPa for mild steel and carbon steel respectively. When the thickness was increased to 30 mm, 19 MPa and 21 MPa for mild steel and carbon steel respectively were obtained. Because carbon steel has a high carbon content than mild steel, higher pressures were obtained for carbon steel. The analysis of the results shown in figure 12 indicates that a higher pressure would be required to press a harder material.

Deflection against thickness graph.

In figure 34(b), the graph shows how the thickness of the material affect the deflection. With a thickness of 10 mm, the mild steel and carbon steel deflected to 30 mm and 8 mm respectively. At a thickness of 20 mm, the materials deflected to 16 mm for both mild steel and carbon steel at pressures of 12 MPa and 14.5 MPa. When the thickness was increased to 30 mm, deflections of 9bmm and 10bmm were obtained for mild steel and carbon steel. It implies that both the thicknesses and the material properties play a role when using the press. Though the mild and carbon steel have the same size and thickness, yet they produced different pressures. This is as a result of the high carbon content in the carbon steel, producing higher pressure for the carbon steel than the mild steel.

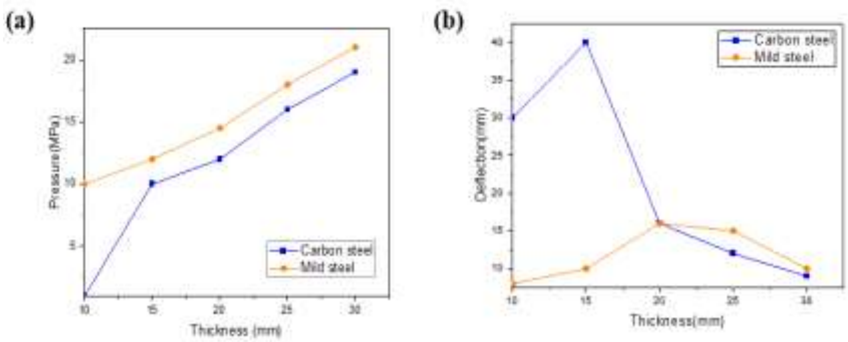


Figure 34: (a) Pressure against thickness graph (b) Deflection against thickness graph.

Source: This study, 2023.

During the practical tests of the hydraulic press machine, the system did not record any oil leakage, overheating, slow pressure build-up or abnormal noise as mostly seen with some locally manufactured hydraulic press machines.

4. Conclusion

A hydraulic press machine was designed and fabricated to address the challenges associated with most locally acquired ones. Mild steel was the main material used to fabricate all the parts of the machine except the table plate arbor and the hydraulic cylinder which are of stainless steel. The Table plate arbor and the hydraulic cylinder are made of stainless steel because stainless steel has a higher yield strength than mild steel. The hydraulic cylinder was produced locally using old used hydraulic cylinder of back hoe machine and machined to the required length and size required. To achieve a workable press machine, various individual components and the assembled press were simulated subjecting it to 25 tons (245166.25 N) maximum load, using static analysis via the ABAQUS software program. The presure and deflections recorded after the press was tested experimentally with different thickness of mild, and carbon steels were reasonable. The result indicates that, deflections for each individual materials corresponds with the pressure exerted on the individual materials mathematically. The hydraulic press machine, having been simulated and tested satisfactorily with a factor of safety of 1.2, can be considered to be strong enough to perform work without failing. The practical test results obtained correlates wth the simulated results with no record of oil leakages, overheating, low pressure and abnormal noise.

5. Recommendation

The article provides a comprehensive overview of the latest advancements in hydraulic press technology, highlighting their increased efficiency, safety features, and applications in various industries. Given the detailed analysis and positive outcomes associated with the use of these modern hydraulic presses, it is advisable for companies in the manufacturing sector to consider upgrading their equipment. The new technology not only offers improved operational efficiency and productivity but also ensures better safety for workers. Adopting these advanced hydraulic presses could significantly enhance production capabilities and competitiveness in the market.

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